FY2008 Annual Report
National Program 203 – Air Quality

Introduction

'Air quality' refers to the combination of the physical-chemical-biological constituents of air masses in the lower atmosphere with which humans, animals, plants, lands, and water bodies of the earth interact. These constituents may take the form of solids (such as suspended particulates), gases (such as oxygen and nitrogen), and liquids (such as water droplets or vapor). We use the term 'air quality' to refer to the state of air with reference to its ability to maintain a high level of human health as the first priority with secondary priorities associated with animal and environmental health. Air quality affects and is affected by human, plant, and animal activities, including life functions. The sweep of winds and the exchange of gases, liquids, and solids between air masses and land and water surfaces affect air quality.

Air quality has both local and global contexts. Odors emitted by a localized source, for example, may be readily detectable by humans within a relatively short distance as the compounds that are identified by the nose become dispersed. On the other hand, particulates of very small size may enter intercontinental air streams and travel around the globe, sometimes for years, as is exemplified by colorful sunsets that follow periods of intense volcanic activity.

Agriculture is a necessary human activity that interacts with air; it benefits from good quality air, and it contributes air pollutants. Agriculture needs air that is free of excessive amounts of such constituents as ozone, dust, suspended pesticides, and odors. But agriculture may also contribute these substances to the air in quantities that are offensive or even threatening to human and environmental health in downwind areas.

The Agricultural Research Service (ARS) developed an Air Quality National Program on the premise that many problems associated with air quality degradation by agriculture can be reduced or eliminated through research to understand polluting processes and application of that understanding to develop solutions. An additional premise underlying the National Program is that air pollution impacts on agriculture can be resolved through research and development.

Component 1: Particulate Emissions.

The objective of this research component is to develop agricultural technologies and practices that minimize contamination of the air by particulates generated during production and processing of food and fiber and provide science-based technology for sound policy and regulatory decisions.

Selected Accomplishments

ARS research is building an understanding of the basic processes leading to particulate emissions, while also addressing immediate needs for emission management strategies. Examples of accomplishments covering the range of research that this approach yields are included below.

Effects of soil physical and chemical properties on dust generation potential studied. Fugitive dust from wind-eroding cropland and rangeland surfaces negatively impacts agricultural sustainability, commerce, and environmental and human health. An understanding of the effects of soil properties on fugitive dust generation is needed to develop management practices for control of dust emissions. Analysis of surface soil samples, including particle size distribution and soil carbon content, collected at locations in the western United States and Northern Mexico by ARS scientists in the Cropping Systems Research Laboratory, Lubbock, TX was used to examine relationships between soil physical and chemical properties and the potential for fugitive dust generation. Dust generation potential (DGP) for rangeland soils was found to be highly dependent on the percentage of soil particles smaller than 50 μm in diameter for situations where soil mineralogy was similar. The relationship between soil particle size distribution and DGP for cropland soils was much less apparent and appeared in some cases to be positively correlated with soil organic carbon. The results contribute to the development of guidelines relating soil management to DGP as part of efforts to develop best management practices. Development of best management practices that limit DGP for soil will result in improved air quality and sustainability of soil resources.

Surface amendments reduce wind erosion of tillage ridges. The furrow region between tillage ridges is often used to trap soil aggregates mobilized by wind or water erosion. However, erosion can degrade ridge height and increase the vulnerability of the furrows to wind erosion. The effectiveness of various soil amendments to stabilize the ridges was tested by ARS scientists from the Wind Erosion Research Lab, Manhattan, KS. Micro-plots were established on 40-cm tall tillage ridges on a sandy soil and subjected to a number of rainfalls exceeding 5 cm and one severe hailstorm. Treatments with a commercial dust control agent alone, or paper sheets treated with the control agent and a pesticide, decreased ridge erosion by more than 50%. Treatments of flyash combined with lime were generally much less effective, because hail penetrated the weak crust. Combinations of low rates of gypsum, composted manure, shredded paper and a mesh material were also tested. Small amounts of shredded paper in combination with gypsum and manure was more effective than these other treatments alone and decreased soil erosion loss up to 40%. The combination with shredded paper allowed sustained infiltration while decreasing runoff and sediment loss. The results indicate that soil amendments may provide a solution to tillage ridge stabilization and will reduce dust emissions from wind erosion. The results are being incorporated into the Wind Erosion Prediction System (WEPS) that was recently transferred to NRCS for use in planning erosion control strategies by producers and land owners.

Flow fields of particulate emissions from poultry facilities characterized. Animal production facilities emit particulate matter affecting air quality that is difficult to measure, as variations in management practices may lead to unusual emission characteristics with substantial impact on downwind concentrations. A particulate emission study was conducted at a poultry facility in north-central IA by ARS scientists from the Ames, IA Air Quality of Agricultural Systems Laboratory. The study focused on the effect of structures and a windbreak on the transport of particulates emitted from three large poultry buildings. A unique aspect of the study was the use of a Lidar system by collaborators from the Space Dynamics Laboratory, Logan, UT. Additional measurements on the emission of ammonia from these buildings were also made and found to be well correlated with the transport of particulates. A significant finding was that the dispersion flow field in the vicinity of buildings and windbreaks was significantly different from the traditional assumption of a Gaussian distribution. This finding demonstrates that new models of particulate dispersion flow fields are needed to describe emissions from animal facilities. The emissions data from this study also helps fill gaps in the basic understanding of emissions from agricultural sources. This data is needed to help develop management strategies for control of emissions and provides a scientifically sound basis for setting regulations.

Dust abatement device for tree nut harvesters developed. Large amounts of nuisance dust are emitted during harvest of pecans and almonds as tree nut harvesters lack dust control devices. A dust abatement device was designed and tested by ARS researchers at Mesilla Park, New Mexico, and Lubbock, Texas, and New Mexico State University researchers to reduce nuisance dust emissions during nut harvesting. The device is designed to be a retrofit to existing harvesters as well as standard equipment on new harvesters. Tests of the device have shown significant reductions of dust from both pecan and almond harvests. There are approximately 1 million acres of tree nuts in the US harvested by about 3300 harvesters. It is likely that a retrofit device might be adaptable and economically feasible for 20% of users, and possibly more depending on future regulatory pressure. This device will enable reductions of dust emissions that lower air quality for areas where nut harvesting occurs, thus protecting the health of agriculture workers.

Component 2: Ammonia and Ammonium.

The objective of the Ammonia and Ammonium Research Component is to develop systems to reduce ammonia emissions from cropping and animal production systems while improving productivity.

Most of this research is performed under the NP206 Manure and Byproduct Utilization Research Program. During 2008 NP206 conducted its five-year retrospective review and held its customer workshop to begin developing its research plan for the next five years. The NP206 Program Retrospective Report is posted to the web and contains summaries of ammonia emissions research conducted over the past 5 years by ARS.

Selected Accomplishments

Ammonia interacts with the acid gases, namely nitric and sulfuric, to form PM2.5 particulates. These particulates contribute to a decrease in air quality. Ammonium nitrate, ammonium sulfate and particulates were measured at two sites in Iowa. One site was at a swine confinement operation and the other in a rural setting not affected by animal operations. Results indicated no significant differences between the sites due in part to the limited sources of the acid gases needed to complete the formation of PM2.5.

Research towards incorporating ammonia volatilization into a whole-farm simulation model being developed by ARS researchers at University Park, PA (the Integrated Farm System Model or IFSM) was conducted. Ammonia volatilization from manure was found to be closely related to the pH at the manure surface, and this surface pH was found to be dependent upon the rate at which carbon dioxide was formed and emitted from the surface. This is an important discovery that will be incorporated into process-based modeling of ammonia emissions from manure. Further experiments substantiating this pH effect are underway.

Component 3: Malodorous Compounds.

The objective of the malodorous compounds component research is to develop practices and technologies for animal production systems that minimize gaseous and particulate emissions and human health impacts and provide information for science-based policy and regulation decisions. Most of this research is also performed under the NP206 Manure and Byproduct Utilization Research Program. There are reports of research on malodorous compounds in the NP206 Program Retrospective Report.

Selected Accomplishments

Reduction of malodorous gases from swine production operations using second generation treatment technologies. An alternative treatment system was evaluated for odor control from swine production operations by ARS scientists in Florence, SC. The system included solid separation and nutrient removal processes. The evaluation included the analysis of six selected odor compounds that are known contributors to malodor in the liquid. Results showed that the concentrations of malodorous compounds were reduced by almost 99%. The majority of this odor reduction occurred during the biological N treatment step. ARS scientists made two additional important advances with odor research: 1) measurement of a suite of odor compounds in water provides quantitative and accurate assessment of odor reduction by treatment technologies; and 2) multi-stage treatment systems incorporating biological nitrogen removal can greatly reduce malodorous compounds in liquid swine manure.

Equilibrium sampling used to monitor malodors in a swine waste lagoon. The concentrations of malodorous compounds in an anaerobic swine waste lagoon were monitored during the late summer to late fall of 2006. While the lagoon was being pumped down, malodorous compounds fluctuated widely, then increased greatly as compared to the period before pumping, and continued to increase as fall progressed. Suspended solids, volatile suspended solids, and total organic carbon increased near the bottom of the lagoon during this same period.

Component 4: Ozone Impacts.

The objectives of the ozone impacts research are to identify ozone-tolerant crop species and varieties, response mechanisms to select or develop tolerant varieties, and production methods that minimize ozone-induced limitations on crop production and quality; and develop science-based information required for sound policy and regulatory decisions.

Selected Accomplishments

Antioxidant compounds in soybean are associated with ozone tolerance. Development of ozone tolerant plants is one approach to alleviate the adverse effects air pollution on agricultural crops. Progress toward improvement of ozone tolerance requires knowledge of the critical points in plant metabolism that can be manipulated to provide protection against ozone stress without sacrificing yield or other desirable characteristics. Soybean genotypes exhibiting different ozone sensitivities were compared to determine whether ozone tolerance was related to the concentration of ascorbic acid (vitamin C) in the fluid surrounding leaf cells, a cellular location where antioxidants have the potential to neutralize ozone before cellular injury can occur. Antioxidant compounds other than ascorbic acid were elevated in the extracellular fluid of the tolerant genotype. Identification of these compounds and their reactions with ozone is a critical topic for future research into the development of ozone tolerant crops.

Increased oxidative stress in leaves of Arabidopsis and soybean noted in response to elevated CO_2 and ozone. In-depth understanding of crop responses to rising levels of atmospheric CO_2 is critical for adapting and predicting future crop responses to global climate change. While exposure of C3 plants to elevated CO_2 would be expected to reduce production of reactive oxygen species in leaves because of reduced photorespiratory metabolism, new results suggest that exposure of plants to elevated CO_2 can result in increased oxidative stress. In Arabidopsis and soybean, leaf protein carbonylation, a marker of oxidative stress, was often increased when plants were exposed to elevated CO_2 or ozone. Two-dimensional difference gel electrophoresis analysis of soybean leaf proteins revealed that elevated CO_2 or ozone altered the abundance of a similar subset of proteins, consistent with the idea that both conditions may involve an oxidative stress. Collectively, these findings add a new dimension to our understanding of global change biology and raise the possibility that oxidative signals can be an unexpected component of plant response to elevated CO_2.

Component 5: Pesticides and Other Synthetic Organic Compounds.

The objective of this research is to develop agricultural production systems that minimize unwanted emission and transport of pesticides. Research on alternatives to methyl bromide is conducted under National Program NP308.

Selected Accomplishments

Efforts to understand factors affecting emissions from agricultural sources are leading to insights needed to manage emissions. Examples of how this understanding is leading to reduced levels of agricultural emissions follow.

Periodic irrigation of the soil surface reduces fumigant emissions to the atmosphere. A method to reduce local volatile organic compounds (VOC) emissions from soil fumigant applications is needed. VOC emissions are a precursor to the formation of ozone, an air pollutant that has harmful effects on human and environmental health, including crops, and the emissions constitute an economic loss for the producer when excessive emissions reduce fumigant effectiveness. A field experiment was conducted in the San Joaquin Valley by ARS scientists from the U.S. Salinity Laboratory, Riverside, CA to measure atmospheric emissions of a soil fumigant after typical injection into the soil of a vegetable grower's field. Irrigation of the soil surface shortly after the fumigant was injected into the soil, and periodically thereafter for several days, resulted in a 50% reduction of fumigant loss to the atmosphere when compared to emissions loss from non-irrigated field soil. The results demonstrate a method to reduce regional VOC emissions, which will help the State of California meet EPA National Ambient Air Quality Standards for ozone, and will help growers of specialty crops minimize the loss of crop protection materials.

Effect of soil moisture and air temperature on pesticide volatilization from surface applications. Pesticide volatilization is the least understood pathway by which pesticides are lost to the environment. As much as 25% of the surface-applied herbicide metolachlor can be lost through volatilization into the atmosphere, thus reducing weed control and potentially contaminating ecosystems adjacent to agricultural land. ARS scientists from Beltsville, MD and Ames, IA have been conducting intensively monitored, long-term pesticide volatilization studies to understand and measure soil characteristics and climatic variables governing field-scale pesticide volatilization. Results show that air temperature and surface soil water content interact so that moist soils can lose twice as much pesticide through volatilization as a dry soil. Soil surface and subsurface features like surface depression and subsurface restricting layers may influence soil water contents which in turn influence agrochemical behavior. The results indicate that if soil water dynamics and meteorological variables for fields with surface applications of pesticides can be measured and modeled, management strategies to reduce pesticide losses to the atmosphere may be possible. Reduced loss of pesticides to the atmosphere will lead to better air quality and more efficient pesticide application with lower cost to producers.

Future Activities

During 2009 the ARS Air Quality Research Program will be integrated with the NP 202 Soils Research Program and the NP 204 Global Change Research Program into the new NP 212 Climate Change, Soils and Emissions Research Program. New air quality research project plans will be developed and reviewed by outside panels convened by the ARS Office of Scientific Quality Review. These project plans are being developed with insights gained from a National Program workshop held during May 2008. During the workshop ARS scientists met with stakeholders and collaborators to determine research priorities for the next five years.

An Action Plan for the NP 212 Climate Change, Soils and Emissions Research Program was developed during the final months of 2008 and serves as a framework for the research to be conducted by NP 212 scientists.